Early Journal Content on JSTOR, Free to Anyone in the World

This article is one of nearly 500,000 scholarly works digitized and made freely available to everyone in the world by JSTOR.

Known as the Early Journal Content, this set of works include research articles, news, letters, and other writings published in more than 200 of the oldest leading academic journals. The works date from the mid-seventeenth to the early twentieth centuries.

We encourage people to read and share the Early Journal Content openly and to tell others that this resource exists. People may post this content online or redistribute in any way for non-commercial purposes.

Read more about Early Journal Content at http://about.jstor.org/participate-jstor/individuals/early-journal-content.

JSTOR is a digital library of academic journals, books, and primary source objects. JSTOR helps people discover, use, and build upon a wide range of content through a powerful research and teaching platform, and preserves this content for future generations. JSTOR is part of ITHAKA, a not-for-profit organization that also includes Ithaka S+R and Portico. For more information about JSTOR, please contact support@jstor.org.

AN APPARENT CORRESPONDENCE BETWEEN THE CHEMISTRY OF IGNEOUS MAGMAS AND OF ORGANIC METABOLISM

By Henry S. Washington

GEOPHYSICAL LABORATORY, CARNEGIE INSTITUTION OF WASHINGTON

Received by the Academy, October 5, 1916

In a recent paper[1] it was shown that potassium and magnesium on the one hand, and sodium and iron on the other, tend to vary together in igneous magmas and the minerals formed from them. That is, igneous rocks and minerals which are high in potassium contain, (of the two), much magnesium and but little iron; while if the rock or mineral is dominantly sodic iron will be high and magnesium low, if these are present. This relation seems to be independent of the silicity (amount of silica) and but slightly modified by the amount of calcium.

The object of the present note is to call attention to what appears to be a congruous relation of these pairs of elements in the organic world —briefly stated, it would appear that, of the four, iron and sodium are necessary for animal metabolism, (magnesium and potassium very much less so); while magnesium and potassium are essential to vegetable metabolism, the other pair being of minor importance.

This correspondence is indicated by the following considerations, all of which are well-known to biologists, so that it is only in their collocation and the pointing out of an apparent congruity in the chemistry of the mineral with the animal and vegetable kindgoms that there is any novelty.

It is well-known that the blood pigments of the higher animals, hemoglobin and its congeners and derivatives, are protein bodies which contain iron as an essential constituent, and it has been suggested[2] that this element acts as the oxygen carrier in the vital processes in which the blood plays the all-important part. In the blood plasma sodium is an important constituent, its amount being several times that of the potassium, though the latter element is, apparently, more important in the cells. The amount of magnesium in the plasma is also very small.

As stated by one authority[3] it would appear that "potassium compounds are replaced in the [animal] organism by sodium chloride," and that as a consequence "common salt is, not only a condiment, but a necessary addition to the food." The universal and necessary use of sodium chloride in food by man and many of the higher animals need only be mentioned.

In plants, on the other hand, the active metabolic agent which enables the organism to assimilate carbon from the CO_2 of the atmosphere is chlorophyll, and it is now well-known through recent researches[4] that this is a protein compound which contains magnesium as an essential constituent. In this connection it is of especial interest to note that chlorophyll is very closely related chemically to hemoglobin, the formulae and apparently the constitution of the two being almost identical;[5] except that the animal metabolic agent is an iron compound and the vegetable agent is one of magnesium, and that the former contains slightly more oxygen than the latter. In this similarity we are reminded of the association and mutual isomorphous replaceability of iron and magnesium among minerals.

In plants again, in contradistinction to animals, of the two alkali metals, "potassium, unlike sodium, is essential to plant life."[6] Water culture experiments have abundantly proved that, of the cations potassium, magnesium, and calcium are necessary to plant life, though a small amount of iron is requisite to the formation of chlorophyll, in which connection the close similarity between this substance and hemoglobin becomes of special interest. Sodium is not necessary to most plant existence.

Although of subsidiary importance, the relative toxicity of the several cations to animal and vegetable life is of interest, as bearing in the same way as the facts set forth above. It must, of course, be understood that toxicity is largely a matter of concentration and that we have to deal, here very briefly and inadequately, with the *relative* toxicities of approximately similar concentrations of the several elements. It is also to be understood that we shall consider only the four cations (Fe, Na, Mg, K), which here concern us, and disregard others, as Ca, as well as the anions or acid radicals.

To the animal organism the magnesium salts appear to be mildly toxic, or at least are very readily eliminated when ingested into the system, which is only true of the iron salts when taken in much greater amounts. That potassium is largely replaced in the animal organism by sodium has already been noted, and experiments by Loeb[7] and others, which can be but barely alluded to here, show that to many animal organisms potassium is distinctly toxic, its ill effects being neutralized by immersion in solutions of sodium salts.

To the higher plants, at least, the iron salts, especially those of ferrous[8] iron, are distinctly toxic when present in the soil in much more than the small amounts needed for its (possibly catalytic) action in the formation of chlorophyll. Likewise sodium salts are, especially relatively to those of potsssium, decidedly toxic toward most vegetable life, though some plants, even of the highest genera, have become halophytic and have adapted themselves to soils and waters containing relatively large concentrations of sodium salts. Even in these, however, it would appear that potassium is the one of the alkali elements necessary to the plant's existence.

Briefly put, therefore, these relations of activity and toxicity of the two pairs of salts are antagonistic in the two kingdoms; that which is active in metabolism and chiefly necessary for life in the animal being relatively toxic in the vegetable, and vice versa.

Finally it may be pointed out that, according to Reichert,[9] hemoglobin is entirely absent from the lower orders of animals, such as the protozoa, porifera and coelenterata, is rare in the echinodermata, and that chlorophyll is present in some of these, as the protozoa. Thus it might almost be suggested that the nearer the animal organism approaches the vegetable the less the influence of iron and the greater that of magnesium in assimilative metabolism.

The facts thus very briefly and imperfectly set forth seem consistently and collectively to lead to the conclusion that, in general, of the four elements discussed, iron and sodium are, relatively to the other two, jointly necessary to animal metabolism and existence, while, per contra, magnesium and potassium replace them as essentials for plant life. Here we have, then, though opposed in the two types of organic metabolism, the same congruity between the two pairs of elements that has been shown to exist in minerals and igneous magmas. Whether this apparent state of affairs is merely coincidental and due to such external factors as conditions of environment, or whether it is based on some fundamental chemical characters or relations of the elements involved, can not be adequately discussed here.

Thus it might be argued in favor of the first supposition that the presence of abundant sodium in the blood plasma is due to the fact that this may represent the sea water in which the present day animal's ancestors once lived; that the presence of iron in the blood pigments may be ascribed to the existence of this element in two valencies, ferric and ferrous iron, and their ready transformation from one state of oxidation to the other;[10] that the presence of potassium rather than sodium in plants may reasonably be connected with the greater resistance to decomposition and greater insolubility of the potassium than the sodium minerals, and the consequent greater tendency of the former to accumulate in soils; and, lastly, that the fact that chlorophyll is a magnesium compound may be correlated with the ability of this element to act as it does in Grignard's reaction, as has been suggested by Willstätter.[11] The relatively greater toxicity of potassium over sodium, as in Loeb's experiments with Fundulus, may be ascribed to selective absorption or membrane permeability. The connection between these pairs of elements in magmas and minerals may be ascribed to differences in solubility.

Each one of these or other such explanations, taken individually and separately, may be rational and valid; but taken collectively, especially in view of the congruity of the four elements in the mineral and organic kingdoms, they make it appear possible and indeed reasonable to ascribe the correspondence to some fundamental chemical relation between the elements involved, of which such proximate causal nexuses as have been suggested are the consequences. No hypothesis can be offered as to what may be the nature of this relation; only the mere possibility of its existence, based on the correspondences set forth in this and the preceding paper, can be suggested.

[1] H. S. Washington, these PROCEEDINGS, **1**, 574 (1915).

[2] Cf. Reichert and Brown, *Carnegie Inst. Publ.*, No. 116, 24 (1909).

[3] O. Hamarsten (Transl. by Mandel), *Textbook of Physiological Chemistry*, p. 564 (1900).

[4] Cf. S. B. Schryver, *Science Progress*, 3, 440 (1909).

[5] Reichert and Brown, op. cit., 1; Schryver, op. cit., 444.

[6] E. Strasburger et al. (transl. by Porter), *Text-book of Botany*, 173 (1898).

[7] Cf. J. Loeb these PROCEEDINGS, **1**, 473 (1915); **2**, 511 (1916).

[8] It is suggested that the lesser toxicity of the ferric salts may be ascribed to their ready hydrolysis and the consequent formation of very difficultly soluble basic compounds.

[9] Op. cit., 2.

[10] Copper, likewise with two valencies, exists in the blood of certain lower animals, as mollusca, limulus, helix and sepia.

[11] The dependence of plant life on magnesium and of animal life on iron, and the difference in their functions, is expressed by Willstätter as follows: "There are fundamentally two kinds of life, which develop alongside of each other; the anabolic life with magnesium and the katabolic life (of animals) with iron, that is a reducing and an oxidizing life." *See Liebig's Ann. Chem.*, **250**, 65 (1906).

THE OAKS OF AMERICA

By William Trelease

DEPARTMENT OF BOTANY, UNIVERSITY OF ILLINOIS

Received by the Academy, October 13, 1916

For a number of years I have been engaged in a study of the oaks of tropical America. These have not been treated comparatively for a generation, with the result that the extensive collections made within that time have gone into herbaria largely unnamed or wrongly named.